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The Equivocal Extent of Glaciation in the Southeastern Uplands of Australia

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INTRODUCTION

Readers of the literature on Pleistocene glaciation of the Southeastern Uplands of mainland Australia will have noted that two opposing schools of thought have emerged. The first suggestions that glaciation has occurred in Tasmania (Gould 1860) and the Southeastern Uplands of Australia (Clarke 1860) were followed before the end of last century by vigorous dispute over 'glacial evidences' in both areas (for instance, Montgomery 1894 versus Johnston 1888, and Curran 1898 versus Helms 1894). Disagreement about the origin of certain features of the Southeastern Uplands has remained to the present time.

ALTERNATIVE INTERPRETATIONS

Dispute centres around the identification, distribution and significance of ice abraded surfaces, certain surficial materials, and 'cirques'.

(a) *Smooth bedrock surfaces*

(i) Browne and Vallance (1957) describe granitic outcrops as far north as Jagungal in the Snowy Mountains as ice abraded because they are smoothly rounded in form. While these authors admit that evidence such as the rounding of hills is 'amenable to interpretation according to the taste and fancy of the observer' (Browne and Vallance 1957, p. 126), Galloway (1963) points out that granitic outcrops are characteristically rounded whether stripped of regolith by either glacial or non-glacial processes. Many of these 'roches moutonnées' are located near tors that could not have survived the passage of ice (see Galloway 1963, p. 182).

(ii) Massive outcrops of granite bedrock at the head of Dicksons Falls Creek, Buffalo Plateau, Victoria, have been attributed by Costin (1957) to glacial activity because of their association with stepped profiles and 'moraine'. Talent (1955) considers that the stepped profiles are related to major jointing in the granite, that the 'moraine' shows retention of primary joint directions indicating that they developed in situ, and that glaciation need not be invoked to account for any landforms in the Buffalo area.

(b) *Surficial deposits*

(i) Galloway (1963) has argued for a non-glacial origin for the general spread of a regolith rich in rubble and boulders, as well as the moraine-like deposits at Island Bend and the 'David Moraine', all in the Kosciusko area.

(ii) Carr and Costin (1955) regard particular surficial materials in the Bogong High Plains area as glacial deposits whereas some or all of these are regarded by others as non-glacial, e.g. 'a residual soil developed *in situ* on granodiorite' (Beavis 1959, p. 192).

(iii) Contrary to earlier workers, Talent (1965) established that rock rivers of the uplands of Eastern Victoria are cryogenic rather than glacigenic.

(c) *Cirque-like features*

(i) Cirques in the lee of the Kosciusko-Twynam ridge form indisputable evidence for glaciation (Dulhunty 1946, Galloway 1963, p. 186, Moye and others 1969). Almost all cirques mapped elsewhere in the Snowy Mountains (e.g. Browne 1952) have however been regarded by other workers as either valley heads modified by solifluction or nivation hollows in various stages of development (see Ritchie and Jennings 1955, Galloway 1963).

(ii) In the uplands of Victoria, landforms described by Carr and Costin (1955) and Costin (1957) as cirques or cirque-like (by implication glacigenic) have been shown by Talent (1965) to be similar to features far below the elevations where former Pleistocene glaciation might be postulated.

(iii) Accounts urging a glacigenic interpretation of features over large areas of the Southeastern Uplands usually referred to 'cirque-like hollows', 'cirquoid features', and 'cirque-like ex-

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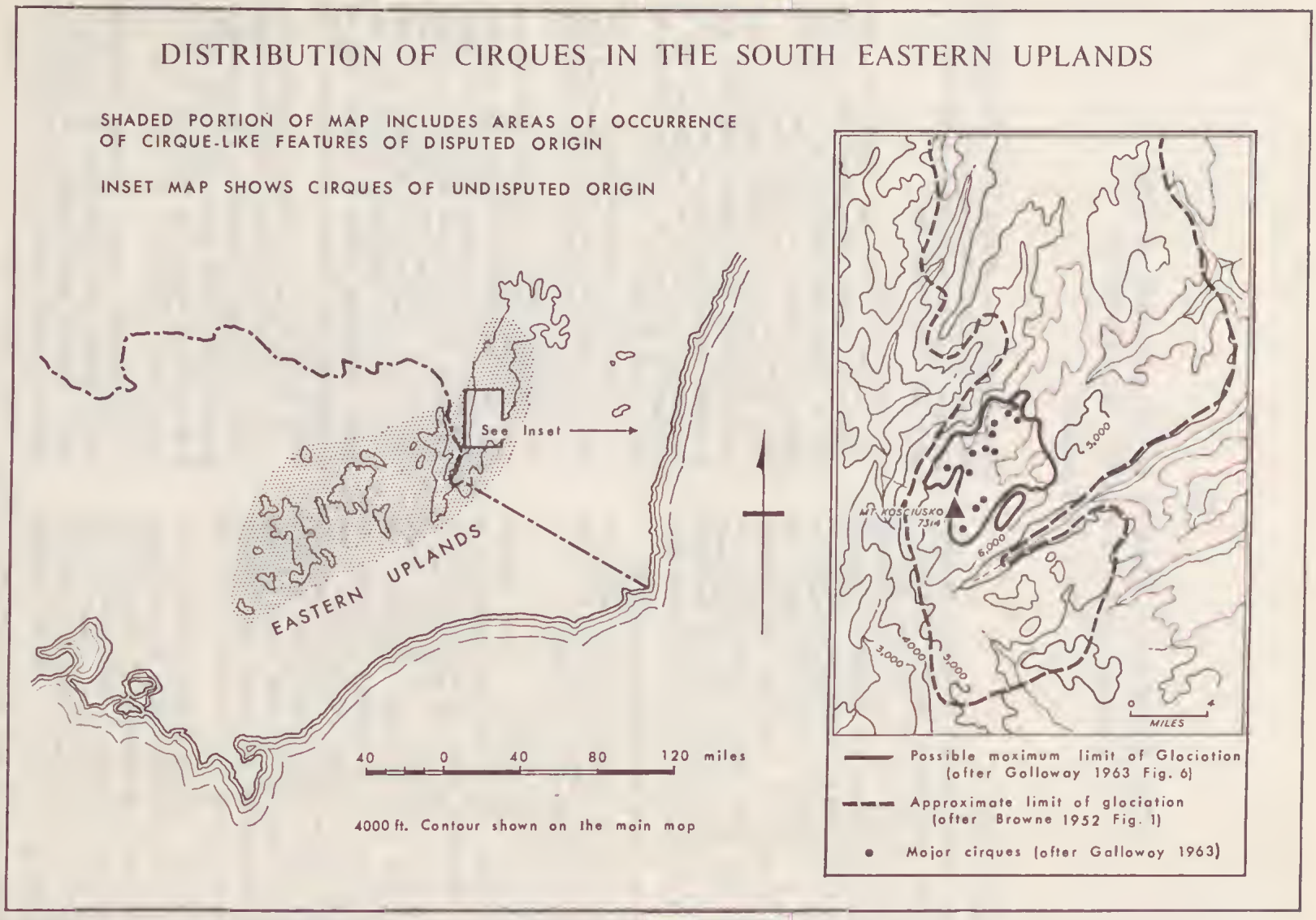

FIG. 1—Distribution of cirque-like features in the Southeastern Uplands according to various authors (e.g. Browne *1952*, *Ritchie 1952*, Carr and Costin 1955, Costin 1957, Galloway 1963). Landforms other than cirque-like features, and with proposed similarities to certain glacial landforms may also be found within the shaded portion of the map.

pansions' (Browne and Vallance 1957, pp. 134, 136), 'cirquated' ridge crests (Ritchie 1952, p. 92), 'cirque-like heads' (Carr and Costin 1955, p. 223) and 'weakly cirque-shaped' features (Costin 1957, p. 236) rather than to cirques. Despite Browne's (1952, p. 33) protestation that 'cirque-heads are almost universal' a cirque-like appearance does not necessarily indicate former glaciation. Indeed it is only after finding such features as over-deepening, striae, and moraine ridges that a cirque-like feature can be regarded with confidence as a glacial cirque.

A result of such conflicting interpretation is that there is a school of thought which supports the proposition that extensive glaciation was part of a pattern of multiple glaciation of the Southeastern Uplands during the Pleistocene (e.g. David 1950, Browne 1952, 1957, 1967, Browne and Vallance 1957, 1963, 1970, Carr and Costin 1955, Costin 1957, Moye and others 1969). Proponents of the other school of thought (e.g. Hills 1940, Ritchie and Jennings 1955, Beavis 1959, Galloway 1963, 1965, Galloway and Erikson 1970, and Talent 1965) maintain a much more conservative view of Pleistocene ice extent (Fig. 1), as well as of evidence advanced in support of multiple glaciation (see Derbyshire and Peterson 1971). Opinions concerning the nature and chronology of multiple glaciation in the Kosciusko area have varied from time to time (cf. Browne 1945, 1952, 1963, and Moye and others 1969).

DISPUTED PLEISTOCENE ICE EXTENT

It can be seen from Fig. 1 that the extent of the Pleistocene ice over the Southeastern Uplands is in dispute, either directly or by implication. Browne (1952, 1957) considered that 1,000 km^2 (400 sq. mls) were glaciated in the Kosciusko region whereas Galloway (1963) has argued that the possible maximum extent of ice was 50 km^2. Hills (1940) and Beavis (1959) did not regard the Victorian Uplands as having been glaciated, whereas Costin (1957, p. 237) considered 'an estimated area of at least 500 square miles probably . . . (have) . . . been affected'.

More recently further disagreement regarding Pleistocene ice extents has become apparent. Moye and others (1969, p. 569) succinctly summarizing the work of Browne (1952) and some others with similar views state that 'the Kosciusko Plateau is the only region on the mainland of Australia with extensive traces of Pleistocene glaciation'. On the other hand Carr and Costin (1959, p. 193) state: 'Physiographic features of a kind accepted as evidence of former glaciation in the Kosciusko region (David 1950) are also to be found in the Victorian Alps and should be accepted by implication as evidence of glaciation in Victoria'. Clearly, the advocates of extensive glaciation in southeastern Australia are in opposition among themselves over the interpretation of the same kinds of landforms.

A GLACIO-CLIMATIC CONSIDERATION

Further field work may resolve the arguments between the two schools of thought. It will be argued here that future syntheses should consider not only geomorphological evidence but also glacio-climatic implications.

A thick ice sheet is envisaged by Moye and others (1969) for the earliest glaciation in the Kosciusko area. Thick ice caps are nourished by net ice accumulation despite an almost complete lack of protection of their surfaces from solar radiation and wind. The accumulation area of an ice cap is therefore above the climatic snow-line. Given a measure of protection from ablation and deflation, snow will accumulate to nourish cirque glaciers, the lower boundaries of ice accumulation (firn lines) of which will lie below the climatic snow-line, and mark the local level of the orographic snow-line.

If a thick ice cap formed over the Kosciusko Plateau during Pleistocene glacial times, would not cirques have been formed on those nearby mountains which were slightly lower than the postulated area of sheet ice accumulation? Perhaps postulation of summit ice domes rather than thick ice sheets constitutes a more realistic reconstruction of Pleistocene glacial conditions. Even so, Manley (1955) has shown that modern summit ice domes of temperate latitudes only exist above the level of the lowest boundary of ice accumulation in immediately adjacent cirques, and that the narrower the summit the higher it must be above this level to support an ice dome (Fig. 2). Cirques, the floors of which approximate to the level of the former firn lines (Flint 1947) should be found at lower levels than that of postulated ice dome glaciation.

However, to date, cirques have not been mapped in areas outside the postulated limits of ice sheet occurrence. Apart from the undisputed glacial cirques in the lee of the Kosciusko-Twynam ridge (see Galloway 1963, p. 186) no glacial cirques have been positively identified, although one feature on Mt. Howitt deserves further consideration. It was regarded as a glacial cirque by Costin (1957). Striations on a 'glacial pavement' on the headwall seemed to support strongly a glacial origin. When the writer examined this feature in December 1968 it was occupied by a snow-patch which was melting and had recently exposed the slopes immediately above the top of the headwall.

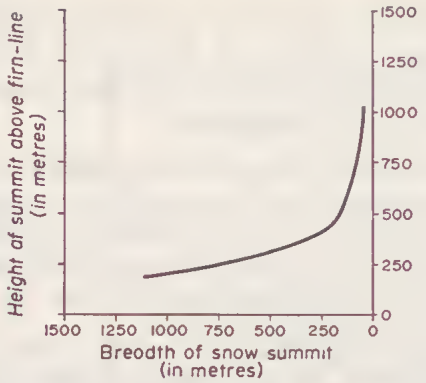

FIG. 2—Manley's Curve showing that the lower limit of ice nourishment in unselective snow accumulation areas is much higher than the lower limit for definite ice accumulation in the lee of nearby ridges—the vertical difference being greater on narrow summits (from Manley 1955, p. 455).

Those slopes bore fresh striations. These were more remarkable for the layer of powdered rock derived from the abrading stones than for the depth of marking. They were therefore thought to have been caused by mass movement of snow the previous winter after the manner described by Costin (and others 1964). The abrasion of the headwalls is not very marked under present conditions: vegetation is little disturbed at the base of the snow-patch and thrives over the floor of the feature which would, therefore, appear to be a relict of a former geomorphic environment. The feature is small; too small to be apparent on the map of the area (State Aerial Survey Victoria, Howitt Sheet 1:63360, form-line interval 100 ft). Further detailed work would be necessary to establish firmly whether it was initiated in glacial or post-glacial times. However, because it is such a small feature and there is no unequivocal evidence for glaciation, it is probably best regarded as a nivation cirque or snow-patch hollow.

SUMMARY

Two schools of thought have emerged upon the question of Pleistocene ice extent in the Southeastern Uplands of mainland Australia and any interpretations of upland geomorphology must acknowledge the two points of view. Future interpretations should also test hypotheses in the light of their glacio-climatic implications. In this context ice-cap glaciation in the Southeastern Uplands implies that cirques would have been formed at levels lower than the lower boundary of sheet-ice accumulation. The absence of such cirques in areas adjacent to those of proposed ice-cap glaciation does not favour the ice-cap hypotheses. Preference may therefore be argued for conclusions derived from the contentions of Hills (1940), Beavis (1959), Galloway (1963, 1965) and Talent (1965) suggesting that much of the 'glacial' evidence is more readily explained in terms of periglacial processes and that ice extent was no more than 50 km² (20 sq. mls, Galloway 1963) accumulated in cirques of undisputed glacial origin in the Kosciusko area. Periglacial processes with total estimated extent in the Southeastern Uplands of some 2,330 km² (900 sq. mls) have received scant attention from advocates of ice-cap glaciation. The more conservative estimates of ice extent imply that a considerable area of the Southeastern Uplands has suffered a period (or periods?) during which a periglacial climate largely determined the rate and form of slope wasting and weathering. Perhaps attention should now be turned to testing this implication in view of the persistence of disagreement over the 'glacial' evidences.

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